

CHAPTER 4

HEATING, VENTILATING, AND AIR-CONDITIONING (HVAC) EQUIPMENT AND CONTROLS

4-1 Description of HVAC systems

Heating, ventilating, and air conditioning (HVAC) of facilities/buildings is accomplished in many ways, depending on the size, configuration, and location of the buildings and the degree of environmental control needed. Small simple facilities in temperate climates can be heated and cooled with a separate heating and a separate cooling unit or with a combination heating/cooling unit. Larger facilities employ refrigeration systems and heating systems which may consist of several large units or centralized systems. Facility complexes may treat each facility separately or provide a dedicated building to house central refrigeration and heating systems. Depending on the HVAC units or systems employed, air is treated through the use of ducts, coils in the ducts, fans to move the air, and dampers to control the air. Liquids are moved by pumps in pipes and controlled by valves, and gases are moved by compressors in pipes or tubing and controlled by valves. Various types and kinds of filters may be used at different locations for air, gas, or liquids. Building air is recirculated, some building air is exhausted, and outside air is introduced in various ways as make-up air. Various energy sources may be used in HVAC systems including oil, natural gas, propane, coal, and electricity. Other equipment such as humidifiers, energy savers/economizers, heat exchangers, expansion tanks, air separators, secondary pumping systems, and smoke management systems may be employed. HVAC systems may also be connected to fire safety and alarm systems.

a. Typical HVAC system. An HVAC system is shown in figure 4-1, Schematic of a typical HVAC system. The system consists of ducts, dampers with actuators, filter, fan, heating coil, cooling coil, piping, valves with actuators, pumps, boiler, chiller, expansion tanks, and air separators.

b. Typical heating/chilled water flow control. A typical heating/chilled water flow control through a coil is shown in figure 4-2, Typical HVAC control loop. The loop consists of a heating/cooling coil, flow control valve, actuator, positioner, temperature sensor, temperature controller, and instrument signal to pneumatic signal converter.

c. Other HVAC equipment. Paragraph 4-3, General HVAC equipment description and operation, explains the operation of various types of boilers and chillers including the packaged units presented here. Variations on HVAC systems and control loops are shown in USACE TM 5-815-3 HVAC Control Systems. For more information on design, maintenance, testing, instrument calibration, and commissioning of HVAC systems see the American Society of Heating, Refrigerating and Air-

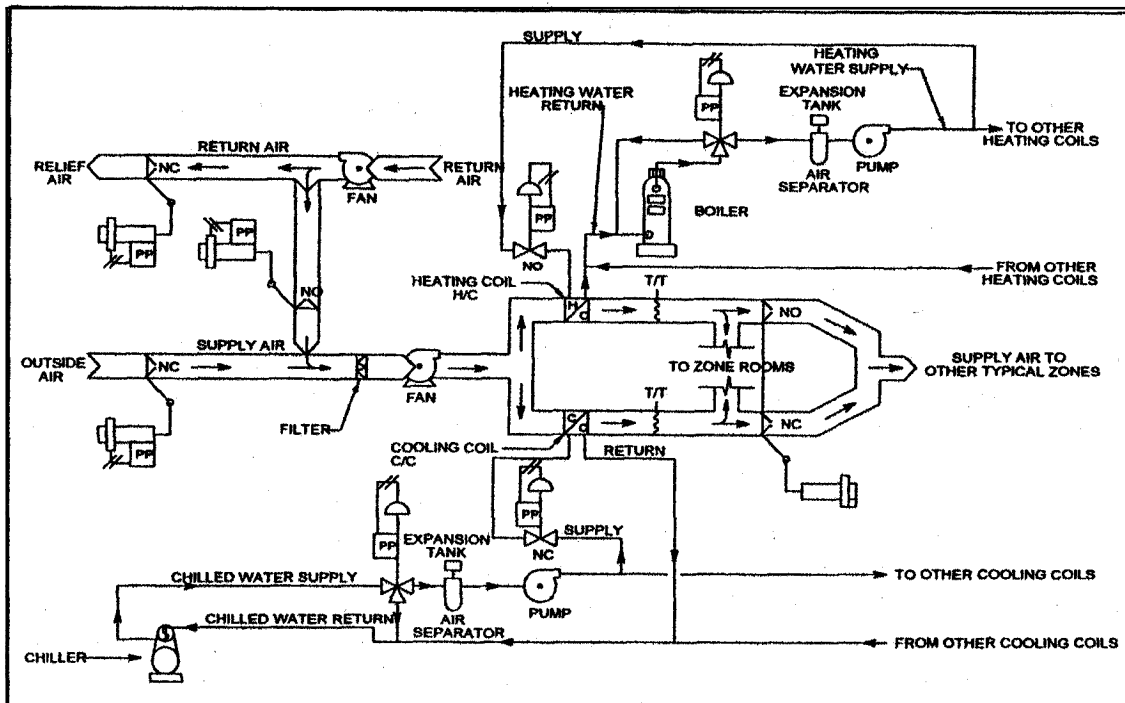


Figure 4-1. Schematic of a typical HVAC system

Conditioning Engineers, Inc. (ASHRAE): Guideline 1-1996, The HVAC Commissioning Process, and The American Society of Mechanical Engineers (ASME): PTC-23, Atmospheric Water Cooling Equipment, and B31.3, Process Piping. The Department of the Army TM 5-692-1 Maintenance of Mechanical and Electrical Equipment at Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance (C4ISR) Facilities, Recommended Maintenance Practices and TM 5-692-2 Maintenance of Mechanical and Electrical Equipment at C4ISR Facilities, System Design Features are also helpful.

4-2 Operation of HVAC systems

Operation of a typical HVAC system and a typical HVAC control loop are discussed in the following paragraphs.

a. HVAC system operation. In the HVAC schematic shown in figure 4-1, interior building air is transported in ducts. A relief air port in the system discharges return air to the outside. An

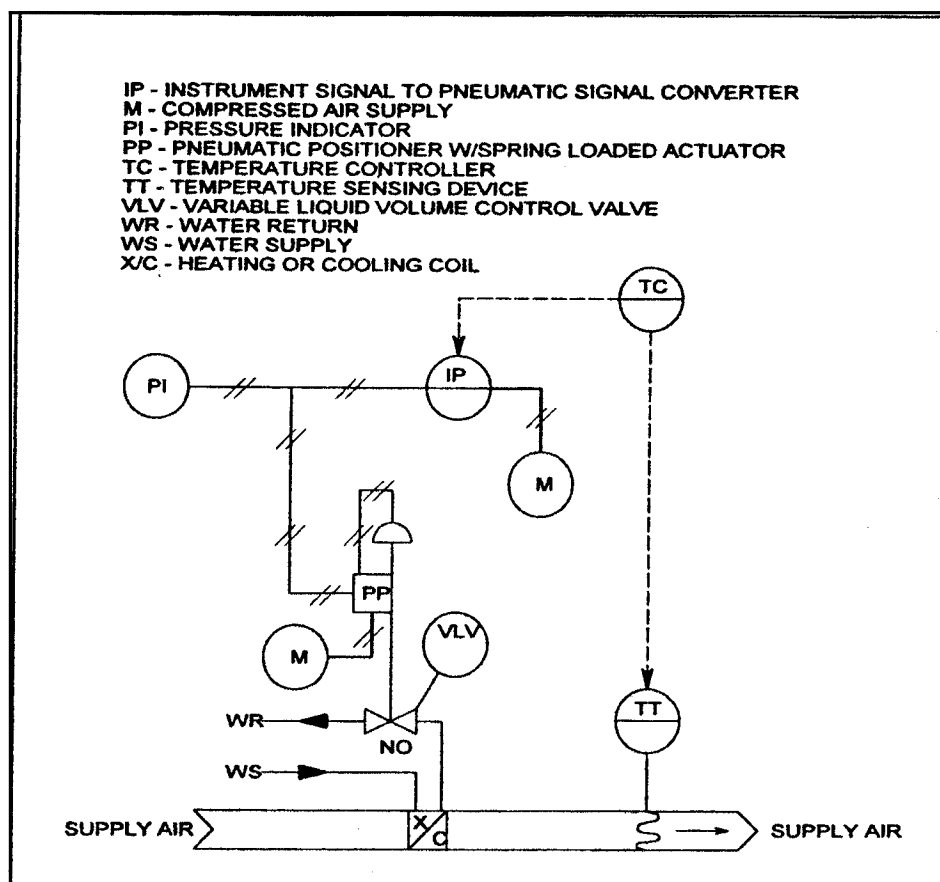


Figure 4-2. Typical HVAC control loop

outside air port allows fresh air to enter the HVAC system. Three modulating dampers adjust the amount of outside air entering the system. Some of the return air from HVAC zones is mixed with outside air, filtered and divided into two streams. One supply air stream passes over a heating coil and is delivered to rooms located within the zone. The other supply air stream is cooled with a chilled water cooling coil, before being supplied to the same rooms within the same HVAC zone. Excess supply air is then mixed together before flowing to other zones. Separate dampers in the heated and cooled air streams adjust air flow to the zone before mixing. Once the mixed air is taken to another zone it will be split again and heated and cooled in a similar way before being supplied to building rooms within the next zone.

b. HVAC control loop operation. Supply air is heated or cooled by passing over a heating coil (H/C) or a cooling coil (C/C) respectively. The flow of water in the coil is controlled by measuring duct air temperature with a sensor TT downstream of the coil. Refer to figure 4-2, Typical HVAC control loop. The measured temperature signal is interpreted by the controller TC and compared against a set point temperature established by a thermostat or an energy management control system (EMCS). To adjust liquid flow in the variable liquid volume (VLV) control valve, the controller produces an instrument signal usually 4 to 20 milliamps. An instrument signal to pneumatic signal converter, IP, converts this signal to a 3 to 15 psig (pounds per square inch gauge) pneumatic signal. Tubing supplies the pneumatic signal to a pneumatic positioner (PP) on the heating/cooling water control valve VLV. The positioner is mechanically connected to a diaphragm actuator indicating valve stem position. The actuator incorporates a spring which maintains the valve in an open or closed position [normally open (NO) or normally closed (NC)] depending on the control scheme, when no air is supplied to the top of the

diaphragm. The pneumatically positioned actuator and VLV valve are often assembled as a unit. The positioner interprets the pneumatic control signal and using the shop air supplied to it, directs more or less air to the side of the diaphragm opposite the spring on the actuator. This air pressure moves the diaphragm which moves the valve stem, changing the amount of liquid flowing through the valve and coil, therefore changing the amount of heating or cooling imparted to the air stream flowing over the coil.

(1) Water flow through the boiler is maintained at a constant rate with a three-way control valve. Temperature sensors in the packaged boiler allow burner controls to adjust fuel flow and therefore the BTU content of the heating water.

(2) Water flow through the chiller is maintained at a constant rate with a three-way control valve also. Temperature sensors in the packaged chiller allow controls to adjust refrigerant flow and therefore the BTU content of the chilled water.

4-3. General HVAC equipment description and operation

The following sections describe some of the equipment used in various combinations to produce an HVAC system. A description of the equipment and its operation is provided.

a. Refrigeration systems. Refrigeration systems are most often supplied skid mounted as a packaged unit. The assembled package includes all major components and controls mounted and pre-wired requiring only that they be anchored to a foundation, hooked up to the hydronic piping system, connected to a treated water supply, and connected to power. There are two basic refrigeration cycles: one compresses the refrigerant gas and the other absorbs the refrigerant at very low pressures.

(1) In the compression refrigeration cycle, HCFC-22 and HFC134a refrigerants remove heat from a medium by changing phases. The refrigerant is compressed in its gaseous phase and passed through a condenser. Outside air or water from a cooling tower passes over the condenser coil to remove heat in one of three ways as discussed below under heat rejection equipment. The refrigerant gas leaving the condenser is then expanded through a valve which lowers its pressure and temperature further until a phase change occurs and a liquid is formed. This now cool, liquid will boil at approximately 20° to 30°F. The liquid refrigerant then passes through an evaporator coil and boils. Water or air flowing through the evaporator gives up its heat to the cold refrigerant making it boil. Entering water temperature is usually 54°F. It is usually chilled to 44°F and is called chilled water. It is treated with cleaning, anti-scaling, anti-fouling, anti-corrosion, and anti-freezing agents. The chilled water is pumped to coils in air handling units (AHU) and ducts where building air or room air is passed over the coil thus cooling the air. Chilled water is often called brine because of salts added to condition the water. When building/room air is passed directly over evaporator coils and the chilled water system eliminated, the system is referred to as direct expansion (DX). DX units are located near the area to be cooled and do not use water as an intermediate medium to condition the air.

(2) Drip pans are placed under cooling coils to collect condensate resulting from cooling building/room air and dropping its dew point temperature. Condensate flows by gravity to a sanitary drain or is collected and pumped to a drain. Refrigeration machines which chill water are often called chillers. Chillers can be packaged units or field assembled units. There are several types of refrigeration machines as discussed in the following paragraphs.

(3) Centrifugal refrigeration machines use centrifugal compressors to compress the refrigerant gas. Centrifugal compressors compress gas as it enters the center of a fluted casting, housing a rotating impeller. The impeller imparts kinetic energy to the gas which turns into potential energy as the gas velocity slows, thus increasing pressure. Compression is a continuous process. One, two, or three stages may be used. Centrifugal compressors are used in large systems.

(4) Reciprocating or positive displacement refrigeration machines use reciprocating or piston type compressors to compress the refrigerant gas. The gas enters a cylinder through a valve when a piston in the cylinder is going down. The valve closes when the piston starts to go up. As the piston approaches the top of the cylinder the gas is compressed by the decreasing volume. An exhaust valve opens when the piston is near the top of the cylinder allowing the compressed gas to exit. The cycle is then repeated.

(5) Rotary screw refrigeration machines use rotary helical screw compressors to compress refrigerant gas or increase the pressure of liquid refrigerant. They are positive displacement machines. The twin-screw compressor consists of accurately matched rotors [one lobe (male) and one helix (female)] that mesh when rotating within a close tolerance common housing. One rotor is driven and geared to the other, turning it in a counter-rotating motion.

(6) Scroll refrigeration machines employ a stationary scroll and a motor driven orbiting scroll to gather refrigerant gas at the circumference and move it through an ever decreasing volume to the center of the scroll where it exists at a higher pressure.

(7) In absorption refrigeration machines the absorption cycle uses a heat-driven concentration difference to move refrigerant vapors (usually water) from the evaporator to the condenser. The high concentration side of the cycle absorbs refrigerant vapors, diluting the absorbent material, usually lithium bromide.

(8) In the evaporator, water at about 40°F is evaporating off the chilled water tubes, thereby bringing the temperature down from the 54°F being returned from the air handlers to the required 44°F chilled water supply temperature. The water vapor is absorbed by the concentrated lithium bromide solution due to its hygroscopic characteristics. The heat of vaporization and the heat of solution are removed using cooling water. The solution is then pumped to a concentrator at a higher pressure where heat is applied (using steam or hot water) to drive off the water and thereby re-concentrate the lithium bromide.

(9) The water driven off by the heat input step is then condensed using cooling tower water, collected, and then flashed to the required low temperature of 40°F to complete the cycle. Since water is moving the heat from the evaporator to the condenser, it serves as the refrigerant in this cycle.

(10) Lithium bromide is the most common absorbent used in commercial cooling equipment, with water used as the refrigerant. Lithium bromide has a very high affinity for water, is relatively inexpensive and non-toxic. However, it can be highly corrosive and disposal is closely controlled. Smaller absorption chillers sometimes use water as the absorbent and ammonia as the refrigerant. Ammonia absorption is used in recreational vehicles and food processing plants.

(11) Absorption chillers must operate at very low pressures, about 1/100th of atmospheric pressure for the water to vaporize at the required ~ 40°F.

(12) Absorption chillers are available in two types, single effect (stage) units using low pressure (20 psig or less) as the driving force and 9 psig steam at the generator, and double effect (two-stage) Units available as gas-fired or steam-driven with high pressure steam (40 to 140 psig). To achieve their improved performance they have a second generator in the cycle and require a higher temperature energy source.

b. Heating systems. To heat building/room air, heating water coils are mounted in ducts. The heating water receives its heat directly from a hot water boiler or from a heat exchanger. Entering the heat exchanger is high temperature hot water or steam which provides heat for the heating water system. Building/room air can also be heated directly in an air heating furnace or by passing over the evaporator turned condenser in a direct exchange heat pump system.

(1) Heating generators are most often supplied skid mounted as a packaged unit. The assembled package includes all major components and controls, mounted and pre-wired requiring only that they be anchored to a foundation, hooked up to the hydronic piping and duct systems, connected to a fuel supply and treated water supply, connected to a stack, and connected to power. Following is a discussion of various heat generators.

(2) Boilers burn natural gas, propane, oil, or coal or use electric to produce steam, high temperature water, and hot water. A boiler can be provided in each building for heating or a central location for heating a complex of buildings. When fuel is burned, the products of combustion are mixed with air and flow over the outside of a tube bundle to heat water inside of the tubes. When electric is used, heating elements are inserted directly into the water to heat it. Depending on temperature and pressure the water will vaporize into steam, become high temperature water, or become hot water. Steam can be piped directly to individual room heaters of various types or can be used in a heat exchanger to condense, transferring the heat of vaporization to heating water. High temperature hot water boilers work in a similar fashion but produce high temperature water instead of steam. Hot water boilers produce hot water from 140 to 180°F for direct use in heating coils to heat building or room air.

(3) Air heating furnaces burn natural gas, propane, or oil, or use electric to produce hot air to be used directly in heating building space or rooms. An air heating furnace is usually provided in each building for heating. When fuel is burned, the products of combustion are mixed with excess air and flow inside of a tube bundle or heat exchanger to heat the building/room air passing over the outside of the tube. When electric is used, heating elements are inserted directly into the air stream.

(4) Heat pumps are discussed below in paragraph 4-3e, Unitary heat pump/air-conditioning equipment.

c. Heat rejection equipment. Heat rejection equipment is most often supplied skid mounted as a packaged unit. The assembled package includes all major components and controls mounted and pre-wired requiring only that they be anchored to a foundation, hooked up to the piping system, connected to a treated water supply, and connected to power. A discussion of heat rejection equipment including cooling towers, evaporative condensers, and air cooled condensers to remove heat from the condenser coil of a refrigeration machine follows.

(1) Water from a cooling tower may be passed through the condenser to remove heat. Under full load conditions the design condenser cooling water inlet temperature is 85°F and leaving temperature is 95°F. The cooling tower water can then be directly exposed to outside air to reject heat from the water. This water is treated for corrosion, fouling, and scaling and is circulated from a basin in the bottom of the

tower. Cooling towers may also use a closed loop for condenser water. A coil is installed in the tower, condenser water is pumped through it and therefore not exposed to the atmosphere. The water basin in the tower now provides water to spray over the tower coil. This with the assistance of a fan removes heat from the condenser water. This basin water is also treated for corrosion, fouling, and scaling.

(2) An evaporative condenser is placed directly over a basin, water from the basin is sprayed, and air is forced over the coils resulting in cooling of refrigerant in the coils. At full load conditions the design entering air dry bulb temperature is usually 95°F and entering air wet bulb temperature is 75°F.

(3) An air cooled condenser has outside air passed over it, the refrigerant in the coil is cooled directly by the air. At full load conditions the design entering air dry bulb temperature is 95°F. Entering condenser refrigerant vapor temperature is 190°F. Leaving condenser refrigerant temperature is 125°F.

d. Air handling equipment and systems. Air handling equipment is designed to condition air in rooms or in designated areas in a building called zones. In an AHU air is moved through filters and over coils to clean, heat, or cool it. Fluid flow in coils or air flow through the AHU can be adjusted for interior environmental control. Following are variations of AHUs.

(1) A single-zone AHU controls interior building air in one building zone. There may be several rooms in one zone.

(2) Multi-zone AHUs control interior building air in two or more building zones.

(3) A variable air volume (VAV) AHU controls interior building air by varying air flow over the coils as opposed to the usual way of varying the flow of the heating water and chilled water through the coils.

(4) A terminal unit VAV (dual duct) unit is located at the end of a heating air and cooling air supply duct and controls interior building air by varying the air volume and mix.

(5) A terminal unit dual duct fan series AHU is located at the end of a heating air and cooling air supply duct and controls interior building air by varying the air volume with the use of local fan(s).

(6) Terminal units with cooling are located at the end of a heated or non-heated air supply duct and include a cooling coil for control of interior building air.

(7) Terminal units with and without fans are located at the end of a conditioned air supply duct and may or may not include a fan for control of interior building air.

(8) DX air units control interior building air by using a DX coil in the air stream. In the DX coil the fluid flowing inside of the coil is a refrigerant. Generally this coil is for cooling but it can be used for heating as well.

(9) Fan coil units are AHUs which control interior building air with a coil to change air temperature and a fan to force the air over the coil and into the building.

(10) Unit heaters usually employ a fan to circulate air within an area or zone and have no supply or return air duct or system of ducts. To control building air, steam coils, hot water coils, electrical elements, or direct gas fired heat exchangers may be used for heating.

(11) Radiant heaters use gas and sometimes electric to heat a ceramic surface. Heat is transferred by radiation to the floor and objects in the room which then heat air by free convection instead of forced convection as is accomplished in most AHUs.

(12) Base heater units consist of an electric element or a finned tube with hot water flowing inside the tube. These units heat interior air by free convection or sometimes incorporate a fan to heat air by forced convection. They heat air in the local vicinity of the heater.

(13) A computer room unit is prepared for controlling the environment in a computer room. This includes provisions for filtering, heating, cooling, and humidity control. Humidity control is usually provided by increased cooling capacity and reheating of the air through additional heating capacity.

(14) A packaged roof top unit is an AHU with its duct, coils, fans, and controls packaged in a weather proof box and is provided with weather proof components to withstand the elements. It is also designed to be supported on a roof with supply and return air ducts located on the bottom of the unit.

(15) An economizer is a gas-to-gas, liquid-to-gas, or liquid-to-liquid heat exchanger which, when practical, is used to salvage waste heat from a process or part of an HVAC system. The waste heat is used to pre-heat heating air thereby reducing the amount and cost of heating. The heating system is therefore more economical to operate with an economizer installed.

(16) Variable speed fans are used in units where a variable volume of air flow is required. Variable speed fans may be provided in place of a central fan and may incorporate inlet guide vanes and/or modulating dampers.

e. Unitary heat pump/air-conditioning equipment. Unitary heat pumps are factory-packaged refrigerant based units. They can provide cooling or heating of interior building air. Both heating and cooling of air can be provided if a refrigerant reversing valve and associated controls are included. This valve reverses the flow of refrigerant transforming the evaporator into a condenser and the condenser into an evaporator. In this way heat can be moved (pumped) from inside building air to the outside in the summer, and from the outside to inside building air in the winter. Provisions are provided to collect condensate from cooling interior air and connection to a drain is needed. Heat pumps and air-conditioning equipment are available in a number of application categories which include the following.

(1) A packaged terminal heat pump (PTHP) unit is designed to be installed at the end of a building interior air supply duct. It includes appropriate duct connections, coils, fans, and controls packaged in one box. It is also designed to be supported from overhead.

(2) Single packaged units have their duct, coils, fans, and controls packaged in one weather proof box and are provided with weather proof components to withstand the elements. They are designed to be located outside and supported on a concrete pad or steel frame from the bottom with supply and return air ducts located horizontally or vertically. Console under window units are also available without duct connections.

(3) A roof-top packaged unit has its duct, coils, fans, and controls packaged in a weather proof box and is provided with weather proof components to withstand the elements. It is also designed to be supported on a roof with supply and return air ducts located on the bottom of the unit.

(4) Split heating, air conditioning, and heat pump units have their ducts, coils, fans, and controls packaged in two boxes. A weather proof exterior box for the compressor, condenser coil, condenser fan, and controls is designed to be supported on a concrete pad or steel frame from the bottom. An interior box is provided with supply and return air duct connections, fan, and drip pan. Connections for refrigerant tubing are provided on both boxes. This tubing is routed as needed and insulated to prevent heat loss or gain in the refrigerant and to prevent condensate from forming on the tubing.

f. HVAC control systems. HVAC control systems are used to control heating, cooling, and ventilating of interior building/zone/room air and are also used in fire safety control schemes.

(1) Direct digital control (DDC) HVAC control systems use sensors, electric actuators, and microprocessors to provide a marked upgrade in system functionality over that attainable with pneumatic control. DDC systems provide operators the ability to remotely monitor existing conditions, change setpoints, diagnose, and sometimes fix problems from a workstation or laptop PC. A single operator could monitor many buildings with DDC control, in addition to performing other operating and maintenance (O & M) tasks. Energy management and reporting functions improve operational efficiency and cost savings. Operational problems can be identified early and fixed before they become larger and more expensive. DDC systems involve vendor-specific application software and a communications network. Each software application provides varying degrees of flexibility and a unique software approach to DDC. The systems are often incompatible.

(2) Fire safety air moving systems provide fire safety to air zones and to stairwells by moving air or smoke. These systems provide for smoke removal only or air pressurization only to help keep areas clear of smoke and provide fire control. They may also use a combination of smoke removal with air pressurization to isolate an air zone for fire safety control.

(3) EMCS manage heating and cooling in a building or zone of a building according to programmed time and temperature schemes for efficient use of energy.

(4) Hydronic systems supply controlled chilled and heated water to cooling or heating coils. In hydronic systems an air separator is incorporated to remove air from the water and an expansion tank is provided to account for changing density in the water. Secondary piping systems are used to circulate water in secondary loops located in different buildings or zones which branch off of the main or primary heating or cooling water supply loop.

(5) Ventilation systems provide circulation of controlled conditioned and filtered air to building zones or rooms and incorporate exhaust air relief and make-up outside air.

g. Smoke management systems. HVAC systems can interface with fire detection/alarm systems. When HVAC control systems interface with fire systems, signals from the fire system are used to take action to minimize the fire and/or provide safe shut down of equipment.

(1) Smoke management systems can use smoke dampers to inhibit the passage of smoke from one zone to another. By appropriate opening and closing of smoke dampers in HVAC ducts, building zones free of fire can be pressurized with air while the zone with the fire can have smoke pulled from it.

(2) Fire dampers are dampers which close when a fuseable link melts and permits the damper to close. This prevents air movement in the duct which helps limit the fire and prevents smoke from flowing in the duct.

(3) Fire stops and smoke barriers are fixed obstacles provided to stop the movement of fire or smoke in walls or ceilings.

(4) Automatic and manual control can be used in HVAC control systems for fire safety and smoke management. Air distribution systems have manually operated devices that stop the operation of supply, return and/or exhaust air, and fans in an emergency. Automatic shutdown capability automatically, according to a predetermined fire management plan, closes dampers and shuts down fans when detectors located in the supply ducts, return ducts, or the building fire protection system detect a fire.

(5) Proper gasketing and sealing of doors is needed to prevent air infiltration into a zone during a fire.

(6) Door release hardware and automatic door openers provide for opening doors for human egress and to control fire and smoke as predetermined in a fire management plan.

h. Ducting. HVAC ducts come in various configurations including round, square, rectangular, and round oval. They are made from iron, concrete, galvanized steel, rigid fibrous, and flexible materials. Metal ducts which supply cooling air must be insulated. Duct systems must be tested for leaks and cleaned before being put into service. Ducts can incorporate heating coils, cooling coils, DX coils, flow switches, pressure switches and gages, smoke detectors, heat detectors, and dampers for system control.

i. Piping systems. Piping systems supply steam, high temperature water, and hot water for heating and chilled water for cooling. These systems also provide make-up water to boilers and return steam condensate to boilers. Condensate from cooling coils is taken to a drain by pipe systems. Pumps move fluids, and steam is moved by pressure differential. Pipe systems may include steam/hot water converters which heat water with steam by using a heat exchanger, finned tube radiators which heat room air by natural convection, control valves operated by the HVAC control system for shutting off and controlling fluid flow, solenoids electrically actuated for stopping fluid flow, and relief valves to prevent over pressure of vessels and systems. Hydronic piping systems incorporate air separators and expansion tanks and must be adjusted and balanced before being put into service. Piping systems must be hydrostatically tested for leaks before being put into service. Piping can incorporate flow switches, pressure switches and gages, thermometers and thermo-wells, solenoids, and relief valves for system control.

4-4. Pre-functional test plan and functional performance test plan for HVAC systems

This manual assumes that individual components and packaged equipment has been tested by the manufacturer. As part of the commissioning effort each component should be checked for damage, deterioration, and failures by a procedure using inspections and tests defined by the specific equipment manufacturers. Equipment manuals from manufacturers identify the minimum required receipt inspections, handling and installation procedures, drawing and wiring verification, field inspection and installation checks, verification of removal of shipping braces, inspection of installation against drawings and nameplates, inspection of components for damage and cleanliness, inspection of insulators and grounding, inspection of anchorage and alignment, adjustment checks, mechanical operation and interlock checks, lubrication application, and verification that local safety equipment is in place.

a. Safety, HVAC. Many tests on equipment involve the use of high voltages, high currents, high pressures, high temperatures, and rotating or moving equipment. These can be dangerous to personnel

and damaging to equipment. A procedure should be followed to insure adequate safety rules are instituted and practiced to prevent injury to personnel performing the tests and other personnel who might be in the local area.

b. Test equipment, HVAC. It is important that in any test program the proper equipment is used. The equipment should be calibrated, in good condition, and used by qualified operators as required by a procedure. Any test equipment used for calibration shall have twice the accuracy of the equipment to be tested. All equipment should be operated in accordance with its instruction manual.

c. Procedures, HVAC. A procedure defining installation inspection and a system test needs to be provided for each system. In the HVAC system there are three basic systems: a heating water system, a chilled water system, and a building air or ventilating system.

d. Inspection checklists, HVAC. Inspection checklists for typical HVAC systems are presented in figure 4-3, Example of a completed DA Form 7477-R, heating water system inspection checklist, figure 4-4, Example of a completed DA Form 7478-R, chilled water system inspection checklist, and figure 4-5, Example of a completed DA Form 7479-R, ventilation system inspection checklist.

e. HVAC equipment detail. Further commissioning pre-functional test and functional performance test detail for equipment, components, and HVAC systems are found in the Department of Commerce: NISTIR 4758, NTIS PB92-173012INZ, HVAC Functional Inspection and Testing Guide and the Department of Energy: Model Commissioning Plan and Guide Specifications, USDOE, Version 2.05 Sections 15998 and 15999.

4-5. Possible failures and corrective measures for HVAC systems

Table 4-1 on page 4-15 lists general problems that may arise during the testing of equipment and systems along with possible troubleshooting techniques. For all problems, consult equipment and component manuals for troubleshooting directions. Check fuses/lights/breakers/etc. for continuity; check equipment calibration and settings; check for clogged filters and strainers; check for closed manual shut-off valves and dampers; check for improperly adjusted valves, dampers, and equipment; and look for faulty equipment and connections.

HEATING WATER SYSTEM INSPECTION CHECKLIST						
For use of this form, see TM 5-697; the proponent agency is COE.						
SECTION A - CUSTOMER DATA						
1. PLANT East Building		2. LOCATION Washington, DC		3. JOB NUMBER EB-18		
4. EQUIPMENT		5. HEATING WATER LOOP DESIGNATION HHW-02		6. DATE (YYYYMMDD) 20021125		
7. TEST EQUIPMENT Ritchie gas menometer kit, Fluke calibrated multimeter				8. TESTED BY Roger Swanson		
SECTION B - EQUIPMENT DATA						
9. BOILER MANUFACTURER York Shipley		10. MODEL NO SPL 500-6-97493		11. SERIAL NO 63-8384 H32093		12. BTU RATING NA
13. PUMP MANUFACTURER Bell & Gossett		14. MODEL NO BG-452		15. SERIAL NO 87-2602-AG		16. RATED FLOW 25 gpm
17. HP @ RPM		18. RATED NPSH		19. RATED PRESSURE 30 psi		
SECTION C - VISUAL AND MECHANICAL INSPECTION						
20.	CHECK POINT	COND*	NOTES	CHECK POINT	COND*	NOTES
	EXTERIOR OF EQUIPMENT	R		EQUIPMENT IDENTIFICATION	A	
	COMPLETENESS OF ASSEMBLY	A		BRACING	A	
	EQUIPMENT ROTATION	A		LABELING AND TAGGING	A	
	ELECTRICAL/MECHANICAL INTERLOCKS	A		SAFETY INTERLOCKS	A	
	INSTRUMENTS	R		WORKING SPACE	A	
	PROPER GROUNDING	A		ANCHORAGE	A	
	PROPER INSULATION	A		SYSTEM FLUSHED AND CLEANED	R	
	TIGHTNESS OF BOLTED CONNECTIONS	R		COMPARISON TO DRAWINGS	NA	
	PROPER LUBRICATION	A		CONTROL SYSTEM	A	
	WATER TREATMENT	NA		FUEL SYSTEM	A	
SECTION D - CALIBRATION AND SET POINT						
21.	DESCRIPTION					NOTES
	SENSORS Photocell signal level within manufacturers tolerances					
	CONTROLLERS Fireye controller does not indicate any faults.					1
	ACTUATORS Burner Modulating Motor operating range appears to be OK. See note.					2
	RELIEF VALVES CHECKED Relief valve was manually forced open during operation.					3
	FUEL SAFETY VALVES Gas Train safeties were checked. All safeties functioned appropriately.					
SECTION E - HYDRONIC SYSTEM TESTS						
22.	OPERATING MODES	TEMPERATURES	PRESSURES	FLOWS	LEVELS	NOTES
	BOILER	Auto	300 degrees F	15 psi	NA	
	PUMP	Auto	190 degrees F	15 psi	NA	
	HYDROSTATIC TEST	performed annually				
	BALANCE TEST	NA				
	HEATING COIL NUMBER	NA				
	CONTROL VALVES	NA				
	SYSTEM TEST	performed annually				
23. NOTES						
1. Boiler is cycling as would be expected.						
2. Operating range checked through the purge cycle, low fire, and high fire positions.						
3. Steam relieved as expected and the valve reseated after the manually applied pressure was removed.						
*CONDITION: A - ACCEPTABLE; R - NEEDS REPAIR, REPLACEMENT OR ADJUSTMENT; C - CORRECTED; NA - NOT APPLICABLE						

Figure 4-3: Example: DA Form 7477-R

CHILLED WATER SYSTEM INSPECTION CHECKLIST For use of this form, see TM 5-697; the proponent agency is COE.						
SECTION A - CUSTOMER DATA						
1. PLANT East Building		2. LOCATION Washington, DC		3. JOB NUMBER EB-19		
4. EQUIPMENT Carrier System		5. COOLING WATER LOOP DESIGNATION		6. DATE (YYYYMMDD) 20021125		
7. TEST EQUIPMENT				8. TESTED BY Roger Swanson		
SECTION B - EQUIPMENT DATA						
9. CHILLER MANUFACTURER Carrier		10. MODEL NO 19XR		11. SERIAL NO 9210H6115		12. BTU RATING 4254 kW
13. PUMP MANUFACTURER Cummins - Wagner		14. MODEL NO 6BC		15. SERIAL NO 1510		16. RATED FLOW 1,898 gpm
17. HP @ RPM 40 @ 1770		18. RATED NPSH 55			19. RATED PRESSURE 165 kPa	
SECTION C - VISUAL AND MECHANICAL INSPECTION						
20.	CHECK POINT	COND*	NOTES	CHECK POINT	COND*	NOTES
	EXTERIOR OF EQUIPMENT	R		EQUIPMENT IDENTIFICATION	A	
	COMPLETENESS OF ASSEMBLY	A		BRACING	A	
	EQUIPMENT ROTATION	A		LABELING AND TAGGING	A	
	ELECTRICAL/MECHANICAL INTERLOCKS	A		SAFETY INTERLOCKS	A	
	INSTRUMENTS	R		WORKING SPACE	A	
	PROPER GROUNDING	A		ANCHORAGE	A	
	PROPER INSULATION	A		SYSTEM FLUSHED AND CLEANED	R	
	TIGHTNESS OF BOLTED CONNECTIONS	R		COMPARISON TO DRAWINGS	NA	
	PROPER LUBRICATION	A		CONTROL SYSTEM	A	
	REFRIGERANT INSTALLED	NA		WATER TREATMENT INSTALLED	A	
SECTION D - CALIBRATION AND SET POINT						
21.	DESCRIPTION					NOTES
	SENSORS					Pressure, temperature, and condition sensors checked OK
	CONTROLLERS					Carrier control system interfaces with JCI system.
	ACTUATORS					Exercise annually for valve control.
	RELIEF VALVES CHECKED					Exercise annually for valve operation limits.
SECTION E - HYDRONIC SYSTEM TESTS						
22.	OPERATING MODES	TEMPERATURES	PRESSURES	FLOWS	LEVELS	NOTES
	CHILLER	Auto				
	PUMP	Auto				
	HYDROSTATIC TEST	performed annually				
	BALANCE TEST	NA				
	COOLING COIL NUMBER	NA				
	EXPANSION TANK/AIR SEPARATOR	NA				
	CONTROL VALVES	NA				
	SYSTEM TEST	performed annually				
23. NOTES						
*CONDITION: A - ACCEPTABLE; R - NEEDS REPAIR, REPLACEMENT OR ADJUSTMENT; C - CORRECTED; NA - NOT APPLICABLE						

Figure 4-4: Example: DA Form 7478-R

VENTILATION SYSTEM INSPECTION CHECKLIST For use of this form, see TM 5-697; the proponent agency is COE.						
SECTION A - CUSTOMER DATA						
1. PLANT East Building		2. LOCATION Washington, DC		3. JOB NUMBER EB-41		
4. EQUIPMENT		5. AIR LOOP DESIGNATION Section C		6. DATE (YYYYMMDD) 20021204		
7. TEST EQUIPMENT Air flow meter, electrical meter, temperature meter				8. TESTED BY Roger Swanson		
SECTION B - EQUIPMENT DATA						
9. FAN MANUFACTURER Greenheck		10. MODEL NO G-120-B		11. SERIAL NO 73662		12. RATED FLOW 980 cfm
13. FAN TYPE Centrifugal		14. HP @ RPM 1 hp @ 1200			15. RATED PRESSURE 125 static	
SECTION C - VISUAL AND MECHANICAL INSPECTION						
16.	CHECK POINT	COND*	NOTES	CHECK POINT	COND*	NOTES
	EXTERIOR OF EQUIPMENT	A		EQUIPMENT IDENTIFICATION	A	
	COMPLETENESS OF ASSEMBLY	A		BRACING	A	
	EQUIPMENT ROTATION	A		LABELING AND TAGGING	R	
	ELECTRICAL/MECHANICAL INTERLOCKS	A		SAFETY INTERLOCKS	A	
	INSTRUMENTS	A		WORKING SPACE	A	
	PROPER GROUNDING	A		ANCHORAGE	A	
	PROPER INSULATION	A		SYSTEM CLEANED	A	
	TIGHTNESS OF BOLTED CONNECTIONS	A		COMPARISON TO DRAWINGS	R	
	PROPER LUBRICATION	A		CONTROL SYSTEM	R	
	CONDENSATE DRIP PANS	A		FILTERS	R	
SECTION D - CALIBRATION AND SET POINT						
17.	DESCRIPTION					NOTES
	SENSORS					Checked sensors with standard
	CONTROLLERS					Cycled controllers for response
	ACTUATORS					Checked full operation from fully open to fully closed
	FIRE DAMPERS CHECKED					Actuated fire dampers. Checked for proper operation.
	SMOKE DAMPERS CHECKED					Actuated smoke dampers. Checked for proper operation.
SECTION E - SYSTEM TESTS						
18.	OPERATING MODES	TEMPERATURES	PRESSURES	FLOWS	LEVELS	NOTES
	FAN	Speeds as required	68 to 72 F	.125	980	
	DUCT LEAK TEST	On at high speed		.125	980	
	AIR BALANCE TEST	As required	68 to 72 F	.125	980	
	COIL NUMBER	On	68 to 72 F	.125	980	
	COIL NUMBER	On	68 to 72 F	.125	980	
	CONTROL DAMPERS	Moderation of flow	NA	NA	NA	
	SYSTEM TEST	Normal operation	68 to 72 F	NA	NA	
19. NOTES						
*CONDITION: A - ACCEPTABLE; R - NEEDS REPAIR, REPLACEMENT OR ADJUSTMENT; C - CORRECTED; NA - NOT APPLICABLE						

Figure 4-5: Example: DA Form 7479-R

Table 4-1. Possible failures and corrective actions of HVAC system

	Areas to Check
General Controls	
Devices will not close/trip	Check mechanical alignment of limit switches Check interlocks and safeties Check relay and protective device settings and operation Check for mis-wired circuits Check control circuit Check controller set point
Devices trip inadvertently	Check relay and protective device settings and operation Check for mis-wired circuits Check the control circuit Check for system overload or short Check grounds
Boiler	
Will not start or starts but shuts down	Check PLC Check power supply Check controls, switches, starters, and disconnects Check controller set points Check sensors, actuators, and indicators Check fuel supply Check fuel safety valves Check fuel filters Check burner flame safety Check igniter Check blower and blower inlet Check heating water pump, flow and control valve Check feed water supply Check safeties and interlocks to fire protection systems
Incorrect heating water temperature	Check controls and set point Check heating water pump, flow and control valve Check for closed shut off valves

Table 4-1. Possible failures and corrective actions of HVAC system (continued)

Chiller	
Will not start or shuts down	Check Program Logic Controller (PLC) Check power supply Check controls, switches, starters, and disconnects Check controller set point Check sensors, actuators, and indicators Check refrigerant Check refrigerant heaters Check condenser fans Check heat rejection equipment power, pumps, fans, and controls Check water pump, flow and control valve Check safeties and interlocks to fire protection systems
Incorrect cooling water temperature	Check sensors, controllers and set point, actuator/positioners Check chilled water pump, flow and control valve Check expansion tank and air separator Check for closed shutoff valves
Ventilating Fan	
Will not start or shuts down	Check power supply Check controls, switches, starters, and disconnects Check inlet vane and damper actuators Check filter(s) Check safeties and interlocks to fire protection systems
Vibrates	Check motor and fan bearings Check inlet vane and dampers Check impeller condition Check vibration joints and isolators Check air filter(s)
Valves and Dampers	
Will not move	Check for stuck valve stem or damper shaft Check supply air Check positioner linkage adjustment Check pneumatic signal Check actuator shaft, diaphragm, and spring Check controller and controller set point Check safeties and interlocks to fire protection systems